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Programmes Analysis: The Assessment of Innovation

by P. M. S. Jones,
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The Programmes Analysis Unit, with its intended role and aspirations, was described by K. G. H. Binning in the April 1968 issue of New Technology—some 12 months after its formation. Now, nearly five years later, it is useful to compare the realisation with the expectation. In particular the imminent elevation of Technology Assessment to headline status, with the establishment in the United States of an Office of Technology Assessment reporting to Congress, the formation of a new international society, and a threatened spate of conferences, makes it an appropriate time to outline some UK experience in this area.

Since its formation in March 1967, PAU has provided its sponsors (the Department of Trade and Industry and the United Kingdom Atomic Energy Authority) with an interdisciplinary analytical capability, and has been charged with: (a) providing a nucleus of expertise on techno-economic appraisal and evaluation; (b) undertaking specific evaluations; (c) developing or extending techniques; and (d) passing on knowledge and practical experience to others.

Over two-thirds of the total effort (the Unit has 30 professional staff with experience in the economic, scientific, engineering, legal or administrative fields) has been taken up by specific evaluations for the sponsors, including some studies for other departments and the Science Research Council. It is on the experience gained in these evaluations that this article will concentrate.

Some indication of the degree of interest in this area, however, may be gained from the fact that PAU have been visited by official representatives of nineteen overseas countries, have presented papers to fourteen different UK professional and learned societies and have educational links with fifteen higher education establishments, including three in Europe. More importantly, perhaps, close links are maintained with those industrial and consultancy organisations known to have expertise in this area, and industrial seminars are periodically held to exchange views and mutually instruct.

Types of appraisal

Programme evaluation or analysis consists of the collection, structuring and analysis of information relevant to a decision or to policy development, including, as appropriate, a review of alternative options and opportunities. Such evaluation may be used to assist in decisions on the investment of resources in, for example, specific R and D programmes. Alternatively a systematic study of a technological area or an industry may highlight new commercial or social opportunities or threats and help to identify the future consequences of postulated courses of action. These aspects are best illustrated by specific examples.

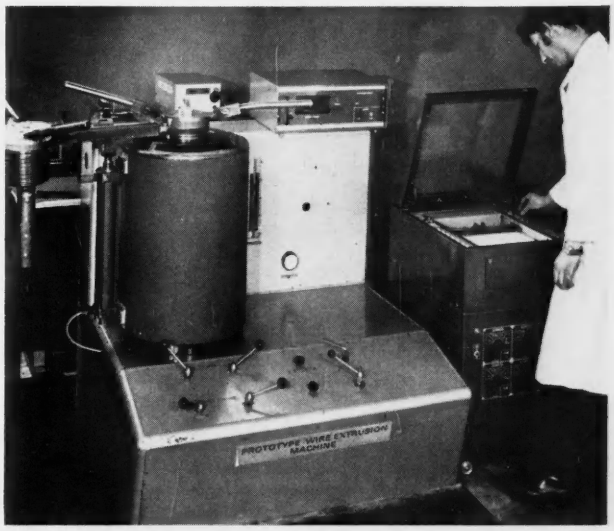


Figure 1. Many of PAU's studies have been concerned with appraisal of proposed new processes. One such process was hydrostatic extrusion. The test applied here was basically one of comparative economics, relating the estimated costs of a wide range of products which could be produced by hydrostatic extrusion to the costs of the same products manufactured by conventional alternatives processes. PAU's report supported R & D expenditure in this area, and led to some restructuring of programmes in hand. The National Engineering Laboratory's prototype machine for controlled hydrostatic extrusion-drawing of wire is pictured above.

Industrial processes

Many PAU studies have been concerned with the appraisal of proposed new processes: eg, the curing of paints by electron beams, or the semi-finishing of metals by new machine tools such as hydrostatic-extrusion presses. The general approach in such cases is to attempt to establish the costs of the new process (including capital costs and those of labour, energy inputs, maintenance, etc), and to compare these costs with those of the established processes. The former are usually obtained by computation and the latter by discussion with industrial firms active in the field. For sensible comparison the computations would have to be on the same basis as industrial calculation and to take into account any grants or tax allowances that the purchaser of the new process or equipment will enjoy. Once having established that the process has some economic attraction, it is necessary to have a detailed understanding of the potential user industry in terms of size, its current and future markets, its attitude to re-equipment and the age and state of its existing plant, etc. If the new process is to be introduced in a static or declining market situation, it will have to compete with existing installed plant which only requires running and maintenance expenditure, whereas, in an

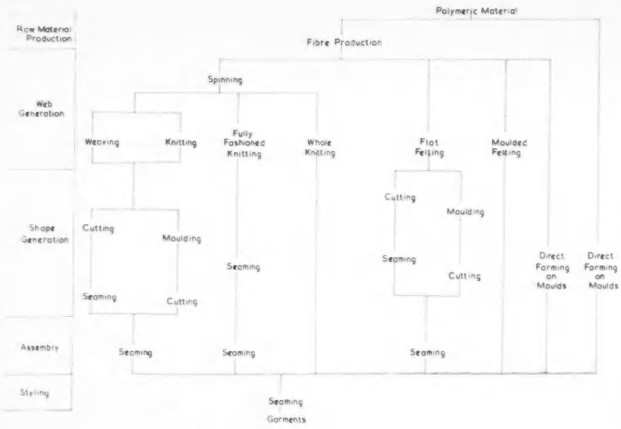


Figure 2. PAU's analysis of the processes of garment manufacture (the flow sheet is given above) suggested areas of the industry in which improvements in performance could most readily be achieved. Studies of the new processes under development for cutting, seaming, and fabrics handling and presentation to the sewing head, indicated what may be possible within the foreseeable future.

expanding market or one in which existing equipment is already worn out, a true full-cost comparison of processes would be appropriate.

The new process often has a significantly higher throughput than the old, and one consequence of its introduction may therefore be a release of labour from the firm adopting it or even a major restructuring of the particular industry when backyard processes are brought on to a modern high-speed production line. For example, the introduction of electron-beam paint curing might well commence with conventionally produced products such as kitchen furniture, but could extend to builders' joinery and result in the supply of pre-painted doors, window-frames, etc, thus encouraging the concentration of the joinery industry in the hands of relatively few firms and reducing the need for on-site labour which is significantly affected by the weather.

The impact of even a relatively simple new technology may therefore be far-reaching. The significance attached to these consequences will depend largely on the nature of the industry concerned, its geographical concentration and the state of regional and national economies. The combination of a high degree of specialisation in machine function with high capacity of the machines themselves makes for a difficult market model; it is, of course, difficult to forecast the effects of a particular technological change on such an institution as the machine-tool industry: but it is almost as difficult to forecast what will happen in the absence of such change. Studies of this type serve to identify the potential commercial viability of new processes or products and hence the justifiable levels of R and D investment. The specific nature of the product can be better defined, the importance of timing and the relative importance of different elements of the development programme can be identified. Additionally, the commercial appraisal of products originating from public-sector laboratories can act as an excellent catalyst to the adoption of new processes and establish more meaningfull dialogue between potential users and developers. For this reason PAU attempts, within the bounds of commercial confidence, to feed the conclusions of studies back to interested firms.

Industry studies

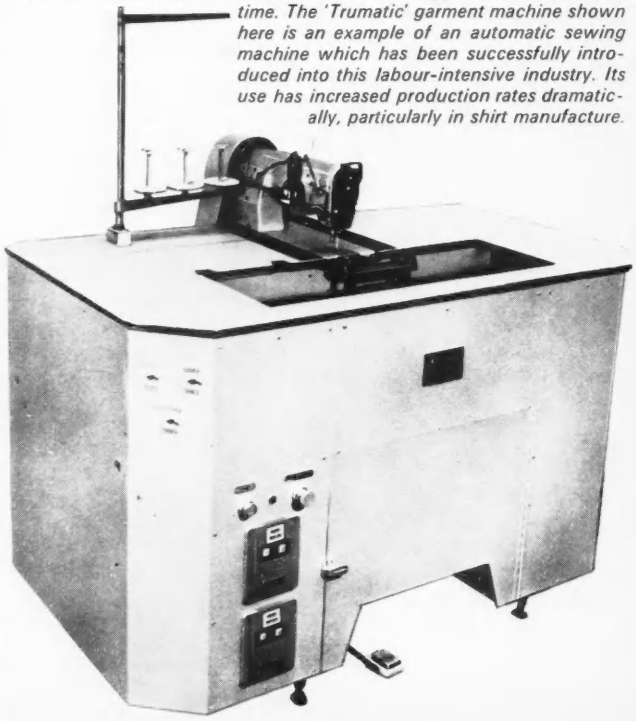
Several studies have been concerned with the future prospects of particular industries and the implications of developing technologies for their future. A typical example concerned the UK garment industry. This industry employs over 350,000 people and has a turnover in excess of £600 million p.a. Its present structure is very largely determined by the fact that its basic tool, the sewing machine, has remained virtually unchanged for a considerable period of time, and is cheap to buy and install. Accordingly, there is comparatively little risk attached to new firms entering the business in times when trade is good, and the loss involved in pulling out in more difficult times is small. Most firms have fewer than 25 employees, although the majority of employees work with firms of over 200 staff, a pattern which is very similar throughout the whole of Europe. Of the employees, 93 per cent are female, and the rate of turnover compared with other industries is relatively high on this account. This rapid turnover results in a serious reduction of efficiency.

The output of the industry has been rising comparatively slowly over the past decade, but the productivity per employee has risen by 25 per cent during the period, due largely to improvements in management practices and organisation. In-depth examination of future garment demand, of the likely available work-force, and of the extent and degree of overseas competition, indicates that increases of productivity of 50-100 per cent will be required over the next decade. Some part of this increase could be gained by further improvement in management practice, but this would be by no means an easy task.

Faced by the problems of increased competition from low-cost sources, a decreasing labour force and a possible reduction in the average level of skill, the industry will have to find some radical means of improving its performance and breaking away from the one-machine one-operator pattern. Analysis of the processes of garment manufacture, with particular attention to costs and labour requirements, suggests areas in which improvement would be most readily acceptable (Figure 2).

Separate studies of the new processes under development for cutting, seaming, and fabric handling and presentation to the sewing head, indicate what may be possible within the foreseeable future, and these processes can be compared with the existing ones in comparative economic terms. The industry is not well equipped to take on radically new techniques of high

Figure 3. PAU's study of the garment industry revealed its structure to have been determined very largely by the fact that its basic tool, the sewing machine, has remained virtually unchanged for a considerable time. The 'Trumatic' garment machine shown here is an example of an automatic sewing machine which has been successfully introduced into this labour-intensive industry. Its use has increased production rates dramatically, particularly in shirt manufacture.



technology, since the size of the individual firms and the technical skills of management militate against them.

To the technologist there is considerable attraction in processes which would completely eliminate the need to produce fibres and then weave these into flat cloth, followed by cutting and reseaming to introduce three-dimensional shape and style. Revolutionary processes involving the direct manufacture of flat or shaped fabrics from fibre are already under development, and three-dimensional shape can be introduced into flat sheet by moulding processes, so that the whole structure of the garment industry could be altered. If such a revolution were to take place, it seems likely that it would occur as the result of initiatives from outside the garment/textile industry itself: eg, from the chemical or fibre-producing industry, which have the technical skills and competence to introduce and carry through such a major innovation. The immediate social consequences of such a major innovation can readily be seen, at least insofar as the predominantly female labour force is concerned.

In this instance, the study has been discussed and published by the Garment NEDC, and several conferences have been held to bring garment and machinery manufacturers together to discuss the industries' future.

Such studies do not replace the normal medium-term planning within the industry, but are intended to provide a wider longer-term viewpoint, and to highlight the consequences of technical and economic change outside the control and remit of the individual firm. Some will indicate that the future is bright and others may spot storm clouds on the horizon. What action, if any, is required is then a matter for government, industry and society to decide, as appropriate.

Environmental pollution

The PAU has been involved in looking at a number of aspects of environmental pollution. The first of these was an examination of the costs of air pollution in the United Kingdom. This was aimed at identifying areas in which research and development were necessary and, if possible, attaching quantitative benefits in monetary terms to such R & D. Air quality in the United Kingdom has improved markedly since the introduction of the Clean-Air Acts, and this has met with general approbation; nevertheless, the general assumption that further improvements in air quality are necessarily desirable requires a more detailed examination.

The first stage of the study was to establish a model of the changes that would take place following a further improvement in air quality (Fig. 4). The mere establishment of such a model goes a long way towards helping one to identify, at least in qualitative terms, the secondary effects of change. For example, one might expect that improved air cleanliness would decrease the demands for cleaning materials, paint, exterior metal work, fabrics, etc. To the consumer these improvements appear as decided gains, but the manufacturer may be faced with a falling market for his product, and this can have one of two effects. If the change is relatively small, then the reductions in fixed plant and labour that the manufacturer can make may themselves be small. Consequently, the price of the remaining products sold may have to be increased, reducing the anticipated economic benefit to the consumer. For larger changes the manufacturers may close down plant and lay off labour, and the consequences of this in specific cases would need to be looked at. In the agricultural sphere the reduction of sulphur-dioxide emissions would have certain undesirable effects, insofar as it acts as a useful fungicide, but on the whole the reduction of pollution from combustion of fossil fuels would be expected to increase crop yields, even if only marginally. This again appears to be beneficial, but improvements in milk yield from cattle on better pasture are of little value if the market for milk or milk products is already saturated. Again, the indirect consequences of an improvement in environmental

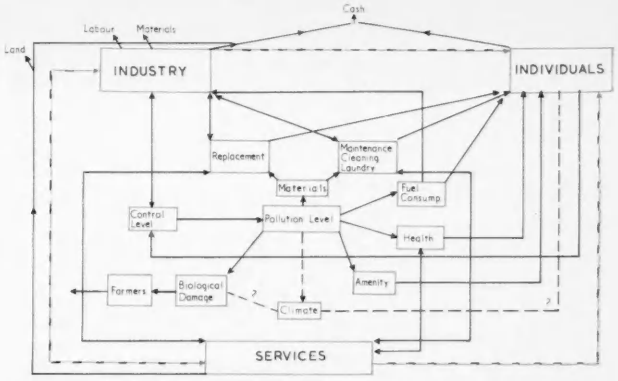


Figure 4. PAU's analysis of air pollution was initiated to assist in guiding Government programmes of research. Current knowledge of air pollution and its effects was surveyed, future trends were examined and the economic and social costs to the UK were assessed. PAU's model of the changes which would follow an improvement in air quality is given above. Savings are represented by arrows from cause to beneficiary, and reduced business by arrows from loser to cause. Cost adjustments are shown by the red-and-black lines.

quality could be a loss of livelihood for those operating farms in fringe areas.

One can work one's way through the whole model examining first and second order of consequences in the same way.

In addition to establishing the benefit associated with postulated changes in air quality, it is necessary to establish the costs of achieving these improvements by use of alternative fuels, high-stack dispersion, scrubbers, precipitators, etc. In principle one can establish the marginal cost of achieving improvements in air quality and the marginal benefit from such improvement, taking into account the first-order and, as far as possible, second-order effects, and one can then establish conceptually some optimum level of pollution above and below which society incurs additional cost. In practice the situation is extremely complicated. The level of damage caused by a particular source depends on its emissions, the temperature and height at which they are released, local topography, local climate, and the people, crops, buildings, etc, in the neighbourhood that can be affected by the pollution. Additionally there are considerable uncertainties in the amount of damage done, due to lack of basic knowledge about pollution effects. At the national level therefore there is little point in making any more than broad generalisations about the desirability of such things as motor-vehicle exhaust control, and it is only when specific proposals are made that it becomes feasible to examine their consequences in full.

The major problem in any study of the environment is one of establishing facts, for there is a dearth of relevant data. For air pollution in the UK we have been fortunate in having the national air-pollution survey, which has monitored smoke and sulphur dioxide at points over the country for a considerable period, but one is still faced with the problem of relating isolated point measurements (of a phenomenon that can vary significantly over a matter of a few metres) to local or regional average pollution levels. Further, one needs to establish whether arithmetic or geometric means are appropriate averaging procedures, or whether thresholds exist in certain damage areas. There is considerable uncertainty about public attitude and public reaction and on the values attached by individuals to different dis-utilities; there is considerable uncertainty on the effects of pollution at normal ambient levels on materials, crops, health, etc. The bulk of the work in assessment of the consequences of changes in environmental quality, or assessment of the consequences of introduction of new control technologies, is in data gathering.

The same situation has obtained in a current study that is

(continued on page v)

Surface Coatings for Use in Space

by P. Walker, Atomic Weapons Research Establishment, Aldermaston

This is the third in a series of articles which we are publishing on various aspects of AWRE's work in the field of organic protective coatings. In the June issue of New Technology the author discussed the factors affecting the adhesion of such coatings to metals. In the subsequent issue he considered the selection of coatings for use on surfaces exposed to radioactive contamination. In the present article he outlines work carried out at Aldermaston to develop coatings suitable for use as thermal-control surfaces in space.

Space is a most exacting and potentially damaging environment for men, machines and materials, as all those who have followed the progress of the recent Apollo missions will have realised. Although the human and mechanical aspects have been fully stressed (and rightly so), little mention has been made of the contribution of the materials used to the success of the various manned missions and unmanned space probes. Take surface coatings, for example. It is probably no exaggeration to say that, without surface coatings in one form or another, few, if any, of the missions could have been completed either safely or successfully. The most important of such coatings are those used as ablative thermal barriers and as thermal-control surfaces maintaining a constant temperature. The work carried out at Aldermaston to develop coatings suitable for use as thermal-control surfaces is described in this article.

The properties required

The properties demanded of surface coatings for use on spacecraft are generally unlike those demanded for terrestrial exposure. Long-term corrosion-resistance is not required, nor are extreme mechanical properties; on the other hand, the resistance to ultra-violet radiation which terrestrial coatings have to display is insignificant compared with that necessary for coatings used in space. Generally speaking, if a paint for conventional use under terrestrial conditions fails in service by loss of gloss, chalking, fading or blistering, this does not lead to immediate failure of the painted component, though long-term failure may result due to corrosion. In contrast, the failure of a coating used as a thermal-control surface in space is likely to lead to a malfunction of the spacecraft or satellite, with consequent rapid and complete failure—and failures of this type cannot be rectified, due to the difficulty of sending a man up with a pot and a brush to repaint the defective area! Malfunctions may arise because of failure to maintain the temperature of certain essential components within the narrow range over which they can function. This is particularly so with batteries. The actual temperature control of a space vehicle is achieved by establishing a precise balance between the heat absorbed and the heat radiated. One 'passive' method of achieving this balance is to use surface coatings; others include the mercury-shutter and the thermal-wick (in which heat-transfer fluid is evaporated at the equipment to be cooled, and then condensed at the vehicle skin). 'Active' methods include thermostatically-controlled heaters, fluid-transport refrigeration and thermo-electric coating; but these techniques have the major disadvantage of requiring power and/or moving parts: and hence, here again, malfunction of one small component may lead to failure of the entire thermal-control system.

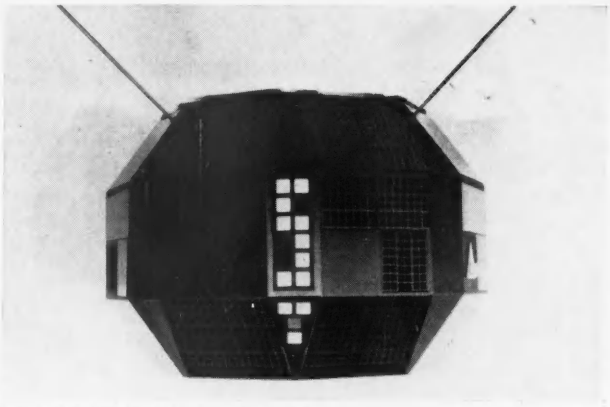
In theory the 'passive' surface-coating method is ideal, but, of course, as with many other simple methods, there are snags, and the technique is still not completely perfected. To achieve perfect thermal control by surfaces, more than one is required; in fact, a combination of four, with varying optical properties, is necessary. The four surfaces comprise a solar reflector, which reflects the incident solar energy and emits infra red; a solar absorber, which absorbs solar energy while emitting only a small percentage of the infra-red energy; a flat reflector, which reflects the incident energy throughout the spectral range from ultra violet to far infra red; and, lastly, the flat absorber, which absorbs the incident energy throughout the spectral range. Of these four surfaces, the solar reflector and flat absorber are of particular interest to the surface-coating chemist, since they can be achieved, at least in part, by the use of coatings. The flat absorber is the easiest of the four surfaces to obtain, and many matt black paints give the desired α_s/E (solar-absorbtance/infra-red emittance) ratio of 0.90. The solar reflector, however, is a different problem, and a great deal of time and effort has been, and is being, expended on producing a surface coating characterised by a low α_s/E ratio (in the region of 0.12-0.24), which would remain stable during long exposures. Obviously there are a great number of factors to consider when developing a space-stable white paint, since the total environment is both varied and complex, encompassing the prelaunch, ascent and re-entry stages in addition to the space environment. The service conditions are therefore most exacting, and include exposure to thermal irradiation, solar irradiation, penetrating radiation, physical impact, and high vacuum—a formidable list of hostile agencies.

Evaluation tests

To sum up, then, the white paint to be used as a solar reflector needs to have: adequate mechanical properties; resistance to thermal shock over the range -70 to $+70°C$; reflectance of over 70 per cent over the range 500-2500 m; and stability to ultra-violet radiation *in vacuo* of $\pm$ 2 per cent of the value *in vacuo* without exposure to such radiation. I have stressed ultra-violet stability in a vacuum deliberately, as this has proved particularly difficult to assess and achieve.

A complete evaluation programme was carried out at AWRE to establish the suitability of various pigments and resins. The specimens were subjected to a variety of physical and optical tests after exposure *in vacuo* to ultra-violet radiation equivalent to that from four suns, and thermal-shock tests were also employed (in the latter case, the sorting test was severe, consisting of heating specimens to 80°C in an oven, and then dropping them into liquid nitrogen).

In initial testing, which was conducted on a wide variety of conventional white pigments, as well as on other white compounds not normally regarded as pigments, very few of the 50-60 specimens tested appeared to be stable to ultra-violet radiation *in vacuo*, even in the absence of a binder: in fact, many of the materials turned dark brown on exposure, and only zinc oxide and zinc, barium and strontium titanates appeared to show promise. Paints based on a methyl-silicone resin and a potassium-silicate binder were also exposed, though many of the coatings based on the silicate binder showed a tendency to crack on cure. The results of these exposure tests, in which the final measurement of reflectivity was made in air, suggested that both zinc oxide and the titanate pigments showed promise, but this inference proved to be optimistic, for, when the paint specimens were removed from the test chamber, panels which were visibly yellow *in vacuo* appeared to become paler in air. This phenomenon—known as 'reversible degradation'—presented a major problem, until an *in-situ* test facility was built which enabled us to carry out the spectral-reflectance measurements while the specimens were still under vacuum.



Black Knight Mark III showing test areas.

The results obtained with this facility were extremely interesting, and in fact changed the whole course of the work. All the pigments tested showed reversible degradation when exposed in a silicone-resin vehicle, and all except the zinc oxide showed this defect in the potassium-silicate binder. It was therefore argued that the zinc oxide was protected by the potassium silicate in some way, and consequently that, if it could be silicate-treated, it would be made suitable for use in a silicone resin without risk of reversible degradation. Such a development would offer distinct advantages, since highly loaded silicate paints tend to crack on cure, and, due to non-wetting, do not adhere well to certain metallic substrates. Exposure work established the validity of these arguments, and a major breakthrough was achieved.

Highly pigmented silicone-resin-based paints, however, have only indifferent mechanical properties, and, where good mechanical properties are of prime importance, it was felt that a silicate-based paint would better meet requirements: this type of paint was expected, for example, to be tough and scratch-resistant and to adhere particularly well to aluminium. Unfortunately early attempts to use zinc oxide as the pigment (and it should be remembered that only zinc oxide was space-stable) were not successful, as the coatings either cracked on cure or failed by complete destruction of the film during thermal-shock tests. Previous experience with other pigments which had produced crack-free coatings with potassium silicate had indicated that cracking defects are not necessarily inherent in silicate coatings. These pigments were of widely varying composition, but a common factor was that their particle-size was greater than that of the zinc oxide employed in the tests at AWRE. It was thought that, if the particle-size of zinc oxide could be increased, crack-free coatings might result. Heat-treatment in a muffle furnace proved to be an effective way of increasing the particle-size, and subsequent tests proved that the resulting pigment could be used to produce crack-free silicate coatings. This finding—that the use of large-particle-size zinc oxide in silicate coatings gives crack-free films—is an important one, and is now covered by *British Patent Application No.* 6826/70.

Spin-off for industry

Of course very few readers will have space craft or satellites to paint, and without doubt many will be wondering how the AWRE work can be of value to them. There could be some 'spin-off', however, particularly in the case of the crack-free silicate coating. Subsequent investigations have shown that this type of coating is flame-resistant and heat-resistant up to at least 700°C without failure. It should therefore be suitable for painting such components as chimney stacks, ovens, furnaces and exhausts, and for a variety of other applications demanding heat- and shock-resistance. Inorganic finishing coats would moreover offer a distinct advantage for use over zinc-rich silicate primers in marine applications.

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PROGRAMMES ANALYSIS (continued from page iii)

being undertaken, for the International Maritime Consultative Organisation, on the economic and biological consequences of deliberate marine oil pollution arising from tank washings, discharge of bilge water, etc, from ships. Here again, the problem is one of establishing what consequences, if any, arise from chronic low-level marine oil pollution; of establishing historic, current, and likely future levels of deliberate discharges; of setting such discharges from ships in perspective in relation to other sources, such as land-based refineries, hydrocarbons emitted from motor-vehicle exhausts, etc. In practice it has proved extremely difficult to establish whether low-level chronic pollution causes any permanent damage of significance.

The techno-economic and cost-benefit examination problems can both guide R & D and help discussions on environmental policy issues.

Lessons to be drawn

This article has dealt briefly with a very small sample of total PAU activity. After 5½ years it is clear that evaluation and analysis have been accepted as an integral part of decision/policy making processes, though only a part. This acceptance has paralleled a change in the scientific and technological environment in the UK which is evidenced by a great awareness of the need to relate R and D to the requirements of society and to examine the possible deleterious (or beneficial) indirect consequences of technological innovation.

Any body, private or governmental, investing resources in technology, or with responsibility for the technology development in society, has need for assessment of one sort or another. At its simplest, this takes the form of market analysis and forecasting; at its most complex, the form of technology assessment. Since technological innovation is the result of a complex interaction of social, economic, technical and even political factors, the term innovation assessment might be more appropriate. In its extreme and largely impractical form, this requires the examination of the potential indirect (and unintended) consequences of innovation to the n'th order before such change is accepted, and this has led to the full process being referred to as 'technology arrestment' in the USA. Studies sponsored by the DTI and the UKAEA have been essentially pragmatic, and have sought to identify secondary and higher-order effects only where these are of significance, and for the majority of innovation the primary intended effects are the only ones meriting consideration.

The direct value of analysis is clear. Indirect benefits arise from the closer identification of objectives and alternative strategies, from the catalytic effect of the analytical process which bridges the gap between the need and the supplier, and from the widening of the circle contributing inputs to decision processes.

Personal contact with the providers and users of technology is an integral part of the appraisal process, and PAU would like gratefully to acknowledge the invaluable help they have received from all sectors of the community, both in the UK and overseas.

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NPL's Ultrasonic Flow Meter

A new device for measuring volume flow rate

by **H. A. Fitzhugh,**
Division of Maritime Science, National Physical Laboratory

The flow of gases in ducts poses problems whose solutions more often than not entail the availability of accurate data on flow rates. Measurement of flow is not, however, an easy exercise. Flow cannot be determined merely by measuring the velocity of the gas at one point in the duct; the usual way is to calculate the required information by numerical integration of data derived from measurements of velocity at many different locations in the flow: and even here the approach adopted depends on whether the flow is steady (ie, time-independent) or unsteady.

NPL's Division of Maritime Science has long been concerned with flow-rate measurement in all its aspects. Its responsibilities include the calibration of, and the maintenance of standards for, such velocity-measuring devices as pitot probes and anemometers, and one could also instance in this context the Division's considerable experience in the use of hot-wire anemometers (which can measure unsteady velocities at one point in a flow) and its development of a particle-velocity meter capable of determining the average velocities of small particles introduced into a highly turbulent flow. Each of these devices has some advantage over its brethren in measuring flow velocities under particular conditions, but to use any of them to measure volume flow demands their installation virtually in serried ranks. Dealing with steady flows is difficult enough, but with unsteady flows the problems are compounded, and the only practical method is to set up a whole array of hot-wire anemometers. Apart from the tediousness of this procedure, it is not unusual to find that the insertion of a mass of measuring instruments into a duct alters the characteristics of the gas flow, so defeating the whole purpose of the exercise.

A good example of the difficulties involved in flow measurement is the cushion system of a hovercraft, in which large and rapid variations of flow can result from contact with the sea. It was this particular example which prompted Maritime Science Division to seek a better way of measuring unsteady volume flows. Our thoughts ran along lines which might be regarded as ambitious: the aim was to develop some method which would not interfere with flow behaviour, which would give a virtually direct reading, and which would be simple to operate. Ambitious or not, we succeeded. The solution arrived at satisfies all these requirements, and the underlying principles are of wide applicability. In fact a prototype has aroused considerable interest from the point of view of measuring rates of flow in such 'conduits' as air-conditioning ducts and the ventilating systems in mine shafts. This prototype measures only steady volume flows, but work is already under way to produce a meter suitable for determining unsteady flow rates.

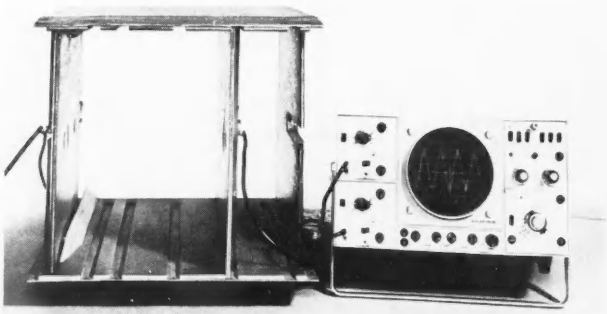

Figure 2. A simulated duct fitted with the NPL flow meter.

As can be seen from Fig. 1, the principal of operation is simplicity itself. An ultrasonic beam projected across the duct is convected downstream by a distance (d) which is directly proportional to the total volume flow rate. The constant of proportionality being the speed of sound, no calibration is required provided that the temperature of the gas is known. The rate of volume flow is equal to the deflection d multiplied by the speed of sound in the fluid. The technique has obvious advantages. The outstanding one is its directness, since local velocities do not need to be measured, but are automatically integrated. There is also no blockage of the duct, and the measurement is hence a true reflection of the flow conditions. And, finally, the technique is effective even if the direction of flow is reversed.

To transmit and receive the ultrasonic beam, use is made of piezoelectric crystals, the transmitter crystal converting an electric signal into a mechanical movement of its crystal face, and the receiver crystal converting a movement of its face into an electric signal. The crystal-face movement at the transmitter creates sound waves, which, because of the high operating frequency (0.5-1.0 MHz), are generated in the form of a beam, without spreading out laterally. The transmitter is located at a

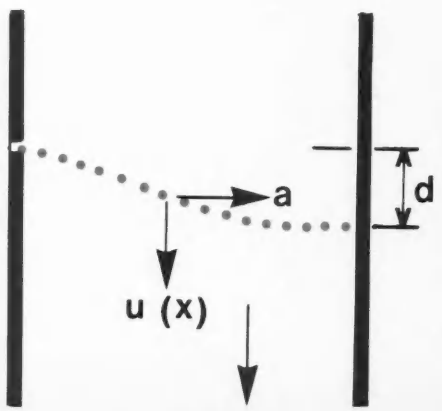

Figure 1. The operating principle underlying the ultrasonic flow meter is illustrated on the right. An ultrasonic beam projected across the flow in a duct is sheared in the flow direction, and the point of impingement is moved downstream by a distance d, *such that*

$$d = \int_0^l \frac{u(x)}{a}\, dx$$

where u *is the local gas velocity,* a *the speed of sound, and* l *the width of the duct. This distance can be related directly to the volume flow rate* Q *(for a unit height of duct), which is the above integral multiplied by the speed of sound; ie,*

$$Q = ad.$$

Provided the distance d *can be measured, and the air temperature (which determines the speed of sound) is known, the flow rate can be calculated.*

fixed point, but the receiver can be moved in the direction of the flow to find the point of impingement of the beam after convection, and hence to establish the distance *d*.

To explore the practicability of the technique, Maritime Science Division has incorporated these principles into the simulated duct shown in Fig. 2. One wall of the duct (that embodying the transmitter) is fixed; the other (containing the receiver) is movable. This flow meter was tested in a wind tunnel, with a grid—not shown in the photograph—placed in front of it to induce turbulence. The meter worked very well, and we hope that the principle will be taken up commercially in the not too distant future—for measurement of both steady and unsteady flow. For unsteady conditions an appropriate number of receiving crystals will be used, in combination with logic circuitry which would distinguish the response of the various crystals and so interpolate the instantaneous position of the beam.

More information: Dr. H. A. Fitzhugh or Mr. G. G. Twidle, Division of Maritime Science, Engineering Fluid Dynamics Branch, National Physical Laboratory, Teddington, Middlesex. Tel: 01-977 3222, ext 3450 or 3309.

news

THE digests for exporters of electrical, water and data-transmission equipment

Exporting firms will be interested in the latest technical digests issued by the Technical Help to Exporters service of the British Standards Institution:

Technical Digest No. 27B, issue 2, series 2, *Digest of technical information for manufacturers exporting electrical equipment for use in industrial situations to Czechoslovakia.*

The digest, which has been updated, includes a schedule of individual items used in industrial locations, ranging from air-conditioning plants to amplifiers and from instrumentation to insulating tape. Against each item are listed the specifications in use, the approval requirements, the installation requirements and other information. Background information includes details of the electricity supplies available, the radio-interference suppression necessary, operations of the foreign trade corporations in Czechoslovakia, etc. Appendices incorporate a directory of organisations which the exporter may require to contact and a description of the approvals procedures.

Technical Digest No. 1007, series 1, issue 1, *Water services and equipment, Netherlands.*

The digest provides information on the Netherlands technical requirements applicable to water services and equipment for personal use and for sanitation and hygiene, and also contains details of the organisations involved in the formulation and enforcement of requirements. Where appropriate, details are given of the availability of equipment approval, the procedures involved and general background notes on practice in the Netherlands.

Technical Digest No. 3501, series 1, *Data transmission equipment: Federal Republic of Germany.*

The Digest provides most of the technical information needed by exporters to enable data-transmission equipment to be approved, licensed and offered for sale in the Federal Republic. The coverage includes equipment connected to public telephone and telegraph circuits and also that connected to private circuits. Some of the items specifically dealt with are: public telex circuits, datex circuits, leased inland telegraph circuits and high-speed broad-band circuits. The digest refers to the specifications, codes of practice and approval procedures applicable to such equipment in the FDR, and gives much useful background information on such things as electricity supply and installation procedures. An appendix gives a directory of organisations in the FDR which the exporter may require to contact.

For details of the above Digests, or other services to exporters, contact Technical Help to Exporters, BSI, Maylands Avenue, Hemel Hempstead, Herts. Tel: Hemel Hempstead 3111.

International Organisation of Legal Metrology

The following draft *International Recommendations* have so far been circulated to member countries:

Polarimetric Saccharimeters.
Serving Measures.
Volume Meters for Liquids other than Water: Supplementary Devices.
Taximeters.
Tyre Pressure Gauges.
Classes of Accuracy for Measuring Instruments.
Verification Agent's Standard Metre Measure.
Weights in Accuracy Classes E_1, E_2, F_1 and M_1.
Verification Agent's Standard Weight.
Gas Meters with Deformable Walls.
Alcoholometry.
Technical Regulations for Non-Automatic Weighing Machines.
Conventional Value of the Result of Weighing in Air.
Gas Meters with Rotating Pistons and Turbine Gas Meters.
Additions to the Vocabulary of Legal Metrology—Fundamental Terms.
Verification of Indenters of Hardness Testing Machines; Rockwell B, Rockwell C and Vickers Systems.
Verification of Hardness Testing Machines; Brinell System.
Verification of Hardness Testing Machines; Vickers System.
Verification of Hardness Testing Machines; Rockwell B and Rockwell C Systems.
Gauge Blocks.
Electrical-Resistance Thermometers for Technical Use.
Medical Syringes.

Copies may be obtained from Standards, Weights and Measures Division, Department of Trade and Industry, Abell House, John Islip Street, London SW1P 4LN.

NELEX '72 Metrology Conference and Exhibition

NELEX '72, the International Metrology Conference and Exhibition to be held from December 12 to 15, 1972, at the National Engineering Laboratory, is designed to provide a forum at which the current state-of-the-art of metrology can be discussed, and views and ideas exchanged. The latest techniques and equipment will be described, and details will be provided of the extensive services and facilities available for industry at NEL. The Conference's eight sessions will cover the following aspects: standards and industry; attitudes to accuracy; multi-axis measuring machines; measurement and control; surface texture; composite gauging techniques; special applications; and optical metrology. The Conference lasts four days, but attendance will be allowed on a daily basis, at an approximate pro-rata charge. Complementing the Conference will be an Exhibition, to which admission is free by ticket. It will include products of all the leading manufacturers of metrology equipment, and will be the most comprehensive exhibition of its kind ever held in Scotland.

More information: Conference Organiser, Birniehill Institute, National Engineering Laboratory, East Kilbride, Glasgow G75 0QU. Tel: East Kilbride 20222, ext. 570.

Warehouse operating costs

The second report of the National Materials Handling Centre's research into *The Costing of Handling and Storage in Warehouses* has now been published. *Report No. 1*, which deals with conventional warehouses, was issued in 1970. *Report No. 2—Highbay Warehouses* discusses the general philosophy of the highbay solution to storage problems and assesses the practical advantages and disadvantages of this approach; it therefore provides a useful guide for management considering following the highbay approach. Both Reports can be obtained (price £2 each) from HMSO. The research underlying the Reports was financed by DTI.

Top-quality production drawings at high speed

MEDALS, the Computer-Aided Design Centre's Modular Engineering Draughting and Library System, is designed to allow engineers to take advantage of a computer's ability to produce top-quality production drawings at high speed.

Data preparation (or drawing definition), where a large part of the total cost of computer-produced drawings lies, has been given considerable attention, and MEDALS is hence particularly simple to use and very adaptable to the varied needs of a drawing office. The system is designed as a collection of self-contained routines and modules called up by the user when defining a drawing or a new module. Each is identified and manipulated by commands and directives input via an inexpensive terminal, such as a teletype. The output drawing may be produced on various graphical devices (including drum plotters, flat-bed draughting machines) or on a storage-tube display in the user's office. MEDALS may be used as it stands or adopted by the user as the basis of a comprehensive draughting system which can be tailor-made to his requirements.

More information: The Chief Consultant, Computer-Aided Design Centre, Madingley Road, Cambridge CB3 0HB. Tel: 0223 63125.

Computer-aided design of circular sewage tanks

A program to aid the engineer in the design of circular sewage tanks has recently become available from DTI's CAD Centre on its time-sharing computer system. Developed by General and Engineering Computer Services Ltd., Liverpool, the program applies specifically to a partially buried, liquid-retaining, open-topped, circular, reinforced concrete tank with sloping floor and central collection hopper.

Simple input data (eg, on tank geometry, bar

diameters and ground conditions) are used to calculate the thicknesses and corresponding reinforcement details required for the tank wall and floor, and to provide information on excavation volumes, concrete volumes and shuttering area. In addition, the program can make any dimensional changes necessary to counteract flotation.

More information: Chief Consultant, The Computer-Aided Design Centre, Madingley Road, Cambridge CB3 0HB (Tel: 0223 63125) or General and Engineering Computer Services Ltd., Computer Consultants, Cunard Building, Liverpool L3 1ES.

Viscosity of gases

Published recently by the National Engineering Laboratory is a new book of tables, giving values for the viscosity of atmospheric gases, which should prove of value both to process-plant design engineers (for heat-transfer and fluid-flow calculations) and to scientists (for calibration purposes).

Recent experimental evidence has shown that the usually accepted values for the viscosity of atmospheric gases have large systematic errors. NEL has collected all the available data and critically assessed them to calculate the most reliable and accurate values to supersede those based on earlier work. The new book covers the viscosity of air, argon, carbon dioxide, helium, hydrogen, krypton, methane, neon, nitrogen, oxygen and xenon at atmospheric pressure. The values are based mainly on new experimental data, the selected data being fitted by a formula based on kinetic theory. The coefficients computed for each gas are given in the tables. The recommended values of viscosity for each gas are presented as a function of temperature at 10-degree intervals for both the Kelvin and Celsius scales, and for most of the gases they cover the range 270-2000 K. The values can be used also for higher pressures, and limits of accuracy are given.

Viscosity of Gases in Metric Units is available (price 75p) from HMSO.

Heat Bibliography 1971

The 1971 *Heat Bibliography* is published this month. Prepared by the National Engineering Laboratory's Fluids Group, it contains over 8,000 references to the world's literature on heat and mass transfer and related subjects. It carries very large sections on chemical and physical properties and heat-transfer processes, and includes in-depth coverage on such aspects as heat exchangers, heat pipes and temperature measurement. The references are grouped under 113 subject headings, and extensive cross-referencing has been introduced, making the publication more useful but not unwieldy.

Heat Bibliography 1971 is available from HMSO, price £5.35p.

New system for calculating stress

A new computer software system for structural stress analysis—the FINESSE finite-element system developed in the Department of Civil Engineering at University College, Swansea—is now being marketed by Software Licencees Ltd., under licence from the National Research Development Corporation, and has already been bought by the Department of Water Affairs of Pretoria, and Ente Nazionale per l'Energie Electrica of Milan. More ambitious in scope, and more efficient to use (being particularly simple in data preparation), FINESSE represents a considerable advance on the well-known FESS system which Software Licencees Ltd. are already marketing by arrangement with the Construction Industry Research and Information Association and Professor Zienkiewicz of University College, Swansea. A mixture of elements can be used, and sub-structures can be represented by one element. The basic element is the 20-node curved isoparametric hexahedron element, familiar to FESS users, which, by changing the boundary conditions, can be made to represent transition shapes, wedges, pyramidal shapes, bricks, etc.

More information: Software Licencees Ltd., Royal Buildings, 2 Mosley Street, Manchester M2 3AN. Tel: 061-236 0969.

PERA's Noise Reassurance Scheme

A new scheme to monitor noise levels in factories, recently introduced by PERA's Noise Control Group, will enable subscribing companies to have their production facilities comprehensively surveyed at six-monthly intervals to ensure that the hearing of employees is not being jeopardised by excessive industrial noise. This Noise Reassurance Scheme will establish whether noise generated is within the limits prescribed by the relevant Code of Practice, and that the noise level in the working environment has not increased during the preceding six-month period. Following each check, the company concerned will be sent a brief report stating that corrective action is needed, or that noise levels are satisfactory, or that the position is deteriorating.

The annual subscription to the scheme is related to the size of the participating company. Remedial measures, if required, can be undertaken, on contract, by the Noise Control Group, including recommending methods of noise control or preparing a custom-engineered solution. Excessive noise emanating from machinery or plant can be acoustically treated at source in some cases. Where this is not possible, sound-dampening barriers or complete enclosures can be provided for the offending machinery.

More information: PERA, Melton Mowbray, Leics. Tel: Melton Mowbray 4133.

Sira gauge assesses blemishes in lenses

An objective, repeatable technique to detect and measure the number and severity of surface blemishes on lenses and similar components has been developed by Sira Institute. Its sensitivity, which is comparable to that of a highly skilled inspector, can be adjusted to suit any user specifications, and the technique offers the means of removing the existing subjective inspection barrier which hinders continuous, automatic lens production. As the next step towards converting the technique into an instrument for production use, Sira is launching a new project to guide development. Members of the group sponsoring the project will be able to emphasise their requirements, detail their particular objectives, and take quick commercial advantage of this latest advance in technology. Organisations wishing to participate should contact Mr. A. J. Kirkham, Optical Systems Division, Sira Institute, South Hill, Chislehurst, Kent BR7 5EH. Tel: 01-467 2636.

Pira text book on VAT

Pira has published a 128-page self-instruction programmed text book on VAT specifically for clerical staff in the paper-making, printing and packaging industries. With it staff can teach themselves the basic principles of the VAT system and terminology, and how to apply these principles to the practical tasks of making out tax invoices, recording VAT in day books and ledgers and filling in the periodical tax returns. The book is obtainable (£1.25 to Pira members; £2.50 to non-members) from Publications Section, Pira, Randalls Road, Leatherhead, Surrey.

Dossier on fuller's earth...

Fuller's Earth is the third in a series of short reports on economic minerals of importance to the United Kingdom which are being compiled by the Institute of Geological Sciences on the basis of information gathered together by the inter-departmental Mineral Resources Consultative Committee with the assistance of firms in the industry. United Kingdom production of fuller's earth has quadrupled since 1945 and is rising rapidly. Production in 1970 was 176,000 tonnes, of which about one quarter (estimated value in excess of £1 million) was exported.

The report describes the geological occurrence of the mineral and existing and potential resources, presents data on annual production and overseas trade, discusses the reasons for the increase in demand, outlines methods of exploiting and processing the mineral, and reviews its industrial applications. The location of the major fuller's earth deposits in the United Kingdom are shown on a map.

Fuller's Earth: Mineral Resources Consultative Committee is available from HMSO (price 42p; 26 pp).

...and on sand and gravel

In the United Kingdom, output of sand and gravel now averages about 115 million tons per annum. Most of it has to be processed to meet the construction industry's specifications, particularly those covering its use in concrete for building and road construction. Nevertheless, sand and gravel are still the lowest priced commodities normally offered for sale by the minerals industry. Marine dredging has become increasingly important in recent years, and the United Kingdom is among the handful of countries exploiting the mineral resources of the sea bed (other than hydrocarbons) on a substantial scale. In 1970, for instance, about a quarter of off-shore production, mostly from the North Sea, was exported to countries that will shortly be our partners in the Common Market.

These statistics are contained in *Sand and Gravel*, the fourth in the series of reports referred to above. Other topics dealt with by the dossier include the distribution of resources (illustrated for England and Wales by a colour plate), demand trends, land-use and restoration, the availability of alternative aggregates, and the structure of the industry.

Sand and Gravel: Mineral Resources Consultative Committee is available from HMSO (price 47p; 29 pp).

More information: Where possible, items in *New Technology* indicate the best sources of further information. Readers are advised also to seek information on matters relating to *New Technology* from the following DTI regional offices: Edinburgh, 031-225 1822; Cardiff 62131; Newcastle upon Tyne 27575; Manchester, 061-832 9111; Leeds 38232; Nottingham 46121; Birmingham, 021-643 8221; Bristol 21071; London and South East, 01-684 9781; Eastern, 01-828 4355. In Northern Ireland, information is given by the Dept. of Industrial and Forensic Science, Belfast 21722.

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